IMPACT MULTIPLIERS FOR THE ECONOMIC EVALUATION OF THE EFFECT OF AGRICULTURAL RESOURCE DEVELOPMENT ON RELATED SECTORS OF THE SOUTHEAST WISCONSIN RIVERS BASIN ECONOMY

REFERENCE REPORT NO. 6

WORKING MATERIALS FOR

SOUTHEAST WISCONSIN RIVERS BASIN

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ECONOMIC RESEARCH SERVICE
FOREST SERVICE

WO-RB-1
3-71

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

Washington, D. C. 20250

Date: May 28, 1971

Subject: Study Name: Southeast Wisconsin Rivers Basin Study

Report Title: Ref. Report No. 6, Impact Multipliers

Status: Final

To: Attention Sidney Weitzman, FS

Economic Research Service
Forest Service
Rural Electrification Administration
Farmers Home Administration
Engineering Division, SCS
Other ______

Liaison Team:

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J W Haas

J. W. HAAS, Director
River Basins Division

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Madison, Wisconsin 53711

May 21, 1971

See Addressed List

Dear Sir:

Re: RB-Southeast Wisconsin Rivers Basin
Reference Report No. 6
Impact Multipliers

Attached is Reference Report No. 6, Impact Multipliers for the economic evaluation of the effect of agricultural resource development on related sectors of the Southeast Wisconsin Rivers Basin economy.

Sincerely,

Richard W. Akeley

Richard W. Akeley
State Conservationist

Attachment

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IMPACT MULTIPLIERS FOR THE ECONOMIC EVALUATION
OF THE EFFECT OF AGRICULTURAL RESOURCE DEVELOPMENT
ON RELATED SECTORS OF THE SOUTHEAST
WISCONSIN RIVERS BASIN ECONOMY

by

John R. Gordon, Economist, ERS

REFERENCE REPORT NO. 6

March 1971

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SUMMARY

Information on the impacts of agricultural resource development on related sectors of the economy is important for resource planning. The Plan of Work for the Southeast Wisconsin Rivers Basin indicates that the United States Department of Agriculture studies will be directed toward the identification of potentially feasible Public Law 566 projects which could be implemented to aid in the solution of a variety of resource management problems. These projects have impacts on the area's agricultural production and, consequently, on the agricultural related industries of the economy. A linear programming model provides the base from which likely changes from present agricultural production can be identified. Impact multipliers to estimate the probable consequences of these agricultural output changes on the related sectors of the economy are presented in this report.

Impacts in the agricultural related industries may be categorized into one of three types. A change in agricultural production will create direct changes of economic activity in (1) industries supplying inputs to agriculture, (2) industries processing agricultural production, and (3) industries supplying consumer goods to those consumers whose income is changed as a direct result of the resource development. Each category represents only the first round of spending in the economy. Associated with each initial change is a

second, third, and finally, an n th iteration of spending. Information on the magnitude and distribution of these respending effects is needed so that informed decisions in resource management can be made.

The purpose of this report is to present impact multipliers as developed from a modified input-output model and demonstrate their usefulness in estimating the economic consequences of agricultural resource development on related sectors of the economy. The particular methods used to construct and test this modified model are not discussed in detail in this report. However, input-output theory is discussed because an understanding of the basic concepts is necessary to interpret the impact multipliers.

Impact multipliers are presented for three subregions within the basin. Economic Subareas One, Two, and Three compose Subregion One, Subarea Four is Subregion Two, and Subarea Five is Subregion Three (Figure 2). All of the economic effects in the related sectors are not confined to industries which are located within the project area. A technique for estimating the impacts accruing to industries within the subregion, the remainder of the basin, and the rest of the nation is presented and demonstrated for a simplified development situation.

The modified model used to develop these impact multipliers represents a simplification of conventional input-output theory. In the final section of this report, several limitations of the procedure are discussed and suggestions are made for further study.

IMPACT MULTIPLIERS FOR THE ECONOMIC EVALUATION OF AGRICULTURAL RESOURCE DEVELOPMENT ON RELATED SECTORS OF THE SOUTHEAST WISCONSIN RIVERS BASIN ECONOMY*

INTRODUCTION

The United States Department of Agriculture is conducting a Type IV River Basin study in cooperation with Wisconsin state and local agencies on the Southeastern Wisconsin Rivers. The United States Department of Agriculture is carrying out its assignment in accordance with a Memorandum of Understanding dated April 15, 1968, between the Soil Conservation Service, Forest Service, and Economic Research Service.

According to the Plan of Work for the study the planning responsibilities of the United States Department of Agriculture are to evaluate the resources and consider solutions to the water and related land problems and needs associated with projected future land use patterns. The studies will be directed toward the identification of potential feasible projects which could be implemented for flood prevention, drainage, irrigation, soil and water conservation, fish and wildlife enhancement, water supply, control and reduction of pollution, and recreational development.

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* This report was prepared by John R. Gordon, an agricultural economist, formerly with the Economic Research Service, NRED, NCRG and currently a Research Associate at the University of Wisconsin.

One major area for which the Economic Research Service has a responsibility in this study is in making impact studies and determining secondary effects. Agricultural resource management activities have impacts in the primary agricultural output sectors and in the related sectors of the economy. A linear programming model provides the base from which likely changes from present agricultural production can be identified. Impact multipliers to estimate the probable consequences of these agricultural output changes on the related sectors of the economy are presented in this report.

The analysis of impacts on the agricultural related sectors begins with the identification of the change in agricultural output. Changes from current levels of agricultural production are likely to result from the final plan of projects proposed by the United States Department of Agriculture. In addition to this final plan, there are at least two other areas in the economic analysis where this type of information is of interest. One of these areas is the comparison of development and no development runs of the linear programming model as discussed on pages 19 and 20 of the Plan of Work. LP

Another part of the analysis conducted by ERS where impact investigations would be interesting is in the evaluation of alternative levels of basin requirements that are specified according to its historical share of the projected national requirements. It is anticipated that alternative levels of requirements will be specified for the basin. Alternative specifications of agricultural

requirements implies alternative effects on the related sectors of the economy. Comparison of these different impacts would produce interesting information for the final plan.

Very often the increases in regional economic activity are transfers from other regions. It is realized that national efficiency is not increased as a result of transferring respending effects from one region to another. Respending effects are important considerations for policy decisions because of their effect on the distribution of economic activity. Impacts or respending effects that are associated with agricultural resource development projects may be categorized into one of three types. A change in agricultural production will create direct changes of economic activity in (1) industries supplying inputs to agriculture, (2) industries processing agricultural production, and (3) industries supplying consumers goods to those consumers whose income is changed as a direct result of the project. Each category represents an initial change or a first round of spending in the economy. Each sector receiving the first round of spending respends the dollars according to its expenditure pattern. This respending is repeated over and over as long as any of the original dollars remain in the local economy. The multiplier is the sum of all of these rounds of spending. Information is needed on the economic interrelationships among various commodity sectors of agriculture and related sectors of the economy in order to estimate these impact multipliers.

A modified input-output model has been developed to allow impact multipliers to be estimated. A detailed description of this modified model is not presented in this report. The purpose of this report is to present the impact multipliers and suggest a procedure to use in analyzing the economic impacts of resource development on the agricultural related sectors of the economy.

Basic Input-Output Theory

Input-output analysis begins with an accounts framework which quantifies the monetary value of goods and services exchanged between sectors (industries) of an economy. 1/ Sales of output by one sector of the economy are purchases of inputs by other sectors. A transactions table, in which sales and purchases between sectors are recorded, is used to determine the degree of interdependency in the economy.

Activity within the economy is separated into exogenous and endogenous sectors. Producing industries which are functionally related to the output of other sectors are endogenous. Sectors such as households, government, foreign trade, investment, and inventories, none of which are commonly thought of as industries whose activity is a function of other industries, may be handled as exogenous sectors. Exogenous sectors supply primary inputs and consume outputs as final demands. If the model has any exogenous sectors it is referred to as open, otherwise it is closed.

1/ For a more complete discussion of basic input-output theory see William H. Miernyk, The Elements of Input-Output Analysis (New York: Random House, 1965); Hossis B. Chenery and Paul G. Clark, Interindustry Economics (New York: John Wiley and Sons, 1959); and Robert Dorfman, "The Nature and Significance of Input-Output," The Review of Economics and Statistics, Vol. 36, No. 2, May 54, pp. 121-133.

If, for example, an economy were divided into three endogenous sectors and one final demand and primary input sector, it could be represented as in Table 1.

Table 1--INPUT-OUTPUT TRANSACTIONS TABLE

		Purchasing Sectors				
		Intermediate Use			Final Demand	Total Gross Output
		1	2	3		
Producing Sectors	1	x_{11}	x_{12}	x_{13}	Y_1	X_1
	2	x_{21}	x_{22}	x_{23}	Y_2	X_2
	3	x_{31}	x_{32}	x_{33}	Y_3	X_3
Primary Inputs (Value-Added)		V_1	V_2	V_3	Y_4	V
Total Gross Outlays		X_1	X_2	X_3	V	Z

The intersection of each row and column for the three endogenous sectors represents a transaction between the purchasing sector (column) and the producing sector (row). The element x_{12} represents a sale by sector 1 to sector 2. Inversely, x_{12} can be interpreted as representing a purchase by sector 2 from sector 1. Similarly, each column entry in the table represents an industry's purchase

during the given time period from other sectors of the economy and each row entry represents an industry's sale to another sector. Transactions within the endogenous portion of the matrix are intermediate in the sense that they have not as yet been purchased for final consumption.

The final demand sector represents sales by industries listed at the left to final use. For example, Y_1 represents sales from sector 1 to final uses. Final demands are exogenous sectors which are unexplained by the model and represent sales of goods and services produced within the region to households, governments, exports, etc.

The value added sector represents purchases by the sector listed at the top of the table of inputs from sources not included in the endogenous portion of the matrix. For example, V_2 represents purchases of inputs by sector 2 from exogenous sectors. The number of these rows varies, but typical entries include payments to households for labor, government payments, imports, and depreciation allowances.

The row total, which is the sum of all intermediate and final demand transactions, is the total gross output for each endogenous sector. The column total, which is the sum of all input purchases from processing sectors as well as primary inputs, is the total gross outlay for each endogenous sector. The total value of output and the total value of outlays for each endogenous sector for the economy must be equal. The entry in the lower right-hand corner, Z, is the total of all transactions in the economy.

By making several assumptions and applying mathematical techniques to the transactions matrix, impact multipliers can be derived. The assumptions and mathematical techniques are discussed in the Appendix of this report.

Consider the impact multipliers that can be determined for a three sector model. In the table below, the b_j's represent sectoral or business multipliers and the l_{ij} coefficients (inverse or interdependence coefficients) indicate how the impact is distributed among the individual sectors.

Sectors	(1)	(2)	(3)
(1) Agriculture	l_{11}	l_{12}	l_{13}
(2) Agricultural Related Industries	l_{21}	l_{22}	l_{23}
(3) Nonagricultural Related Industries	l_{31}	l_{32}	l_{33}
Column sums	b_1	b_2	b_3

A coefficient from the multiplier matrix, l_{ij}, shows the direct and indirect production in sector i required per dollar of final output in sector j. In this three sector model, l_{21} indicates the requirements from the agricultural related industries if agricultural production for final demand changes by one dollar. The other l_{ij} coefficients can be interpreted in a similar manner.

Sectoral (interindustry, business, or output) multipliers can be computed by adding the l_{ij} coefficients in a column of the matrix. The multiplier for a sector, b_j, specifies the total production (direct and indirect) required from all industries to produce a dollar's worth of final output in that sector. If sectors are defined to represent specific agricultural commodities, the sectoral multipliers, b_j's, show the value of production required to produce a dollar's worth of a specific commodity. These multipliers for seven agricultural commodities are presented in this report. Knowledge of the change in agricultural output resulting from the resource development, together with these sectoral (commodity) multipliers will allow calculation of the total value of production created in the economy.

However, despite the attractiveness of the model it does have drawbacks. In making forecasts with the static input-output model, it is assumed that the coefficients do not change from one time period to the next. With the passing of time it is possible that relative input prices will change, new products may appear, and technological progress in production relationships may occur to alter the technical coefficients. Other problems arise because regions are not isolated from one another and therefore the economic activity of a region is not self contained. Leakages from the region will occur and need to be accounted for in the model. On the other hand, the region under investigation will be stimulated by feedbacks from other regions which were initially stimulated by the activity in the study area.

A major problem in the construction of all input-output models is data selection. A survey is generally required to obtain the necessary data for regional studies. Typically, firms are interviewed to determine both the distribution of their sales and of their purchases. Differences in the two sets of data must be reconciled after they are collected. Both the time and expense required in collecting and reconciling data are quite large. In many cases the time and expense associated with obtaining the data are extensive enough to render input-output models financially impractical. Consequently, impact information is needed for many studies in which conventional input-output analysis is economically infeasible. In recognizing this need, Meyer writes,

> In a pragmatic, decision-oriented field like regional economics some attention also might be given to the highly practical question of when and whether more complex research designs yield sufficiently improved results to justify their costs. Particularly relevant would be some empirical tests of the effects of incorporating greater or less interdependence and aggregation into regional forecasting models....In general, regional analysis might benefit from an incorporation of some of the ideas found in modern statistical decision theory and particularly the notion that the costs of obtaining better decisions should be compared with the obtainable yield. 2/

An operational model which is easier to implement and less costly than the usual interindustry analysis is needed for this river basin study to provide estimates of the economic implications of agricultural resource development projects on related sectors of the economy.

2/ John R. Meyer, "Regional Economics: A Survey," in Surveys of Economic Theory, Vol. II, prepared for the American Economic Association and the Royal Economic Society (New York: St. Martin's Press, 1965) pp. 250-257.

This has been true in other studies and several simplifications have been used to develop the necessary data. The data simplifications include using national data (12), aggregating sectors (6, 10), employing a "rows only" approach (9, 26), and constructing the technical coefficients from production relationships (29). The major modification used to develop the model for this river basin study is partitioning of the matrix of technical coefficients and inverting only the agricultural and related sectors block of the economy (8, 21, 23).

It is known that an individual coefficient in the multiplier matrix as determined in the modified model will be smaller than the corresponding coefficient from a fully developed input-output model. The relationship of the coefficients is

$$l_{ij.nm} = l_{ij} - l_{nj} l_{im} / l_{nm}$$

where $l_{ij.nm}$ is the inverse coefficient determined when some sectors are excluded from the endogenous portion of the matrix and l_{ij} is the corresponding coefficient determined when the previously excluded sector is included as endogenous (2).

Since all of the interdependence coefficients are greater than or equal to zero, this relationship shows that, ordinarily, the $l_{ij.nm}$ coefficient will be smaller than the corresponding l_{ij} coefficient. If any of the elements in the interaction term, $l_{nj} l_{im} / l_{nm}$, are equal to zero, $l_{ij.nm}$ will be identical to the corresponding l_{ij}. This extreme case is not likely to occur. However, because of weak structural interdependencies between the agricultural complex

and the nonagricultural sectors, the $l_{ij.nm}$ in the agricultural commodity columns closely approximates the corresponding l_{ij}. Because of the model's modification, the sectoral multipliers for the agricultural commodities, b_j's, presented in this report must be interpreted to represent the impact on agricultural related industries instead of the impact on all industries.

Region, Subregion and Sector Delineation

The Southeast Wisconsin Rivers Basin lies in eastern and southern Wisconsin, north central Illinois, and northern Michigan. [3/] There are portions of two major continental drainage basins in the study area, the Upper Mississippi and the Great Lakes - St. Lawrence. The total drainage area is about 15,530,600 acres, or 24,266 square miles.

The study area is bounded on the east by Lake Michigan, on the west by the Wisconsin and Galena-Platte drainage basins, on the south by the Wisconsin state line, except for the inclusion of the Rock River basin, downstream to Rockton, Illinois, and on the north by the northern boundary of the Menominee River basin in Michigan (Figure 1). The Rock and Fox Rivers drainage areas flow south and west to join the Mississippi River. The other drainage areas flow to the Great Lakes.

3/ Descriptive information is presented in detail in a publication by the author entitled A Description of the Agricultural Economy of the Southeast Wisconsin Rivers Basin, Technical Report No. 1, United States Department of Agriculture (Madison, Wisconsin: March, 1969).

SOUTHEAST WISCONSIN RIVERS BASIN
LOCATION MAP

Figure 1

SCALE 1/2,930,000
SCALE IN MILES

The entire basin includes thirty-four counties in Wisconsin, three in Michigan and two in Illinois (Figure 2). In this impact study the region is defined as synonomous with the river basin area. Because the proposed development will have different impacts in different parts of the study area and considering that one purpose of the model is to measure some of the distribution effects, information is needed by subregion as well as for the entire basin. Isard notes that subregion delineation complicates the problem:

> To determine appropriate hierarchies of regions is still more difficult; and the associated data requirements place still a greater strain on financial resources available for study. 4/

Among other reasons, selection of subregions is difficult because economic activity is related to the size of the area under investigation. All other things being equal, it is desirable to have large subregions because the leakage problem becomes more serious as regions become smaller. For this reason the five economic subareas, previously defined for the river basin study (figure 2), have been grouped into three subregions. Subareas One, Two, and Three in Figure 2 constitute Subregion One, Subarea Four is Subregion Two, and Subarea Five is Subregion Three.

Considering the restrictions as well as the research objective, the following sectors are classified as endogenous. Approximately corresponding sectors used in the 1958 and 1963 national input-output studies are listed in parenthesis after the description of

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4/ Isard, Methods of Regional Analysis, p. 323.

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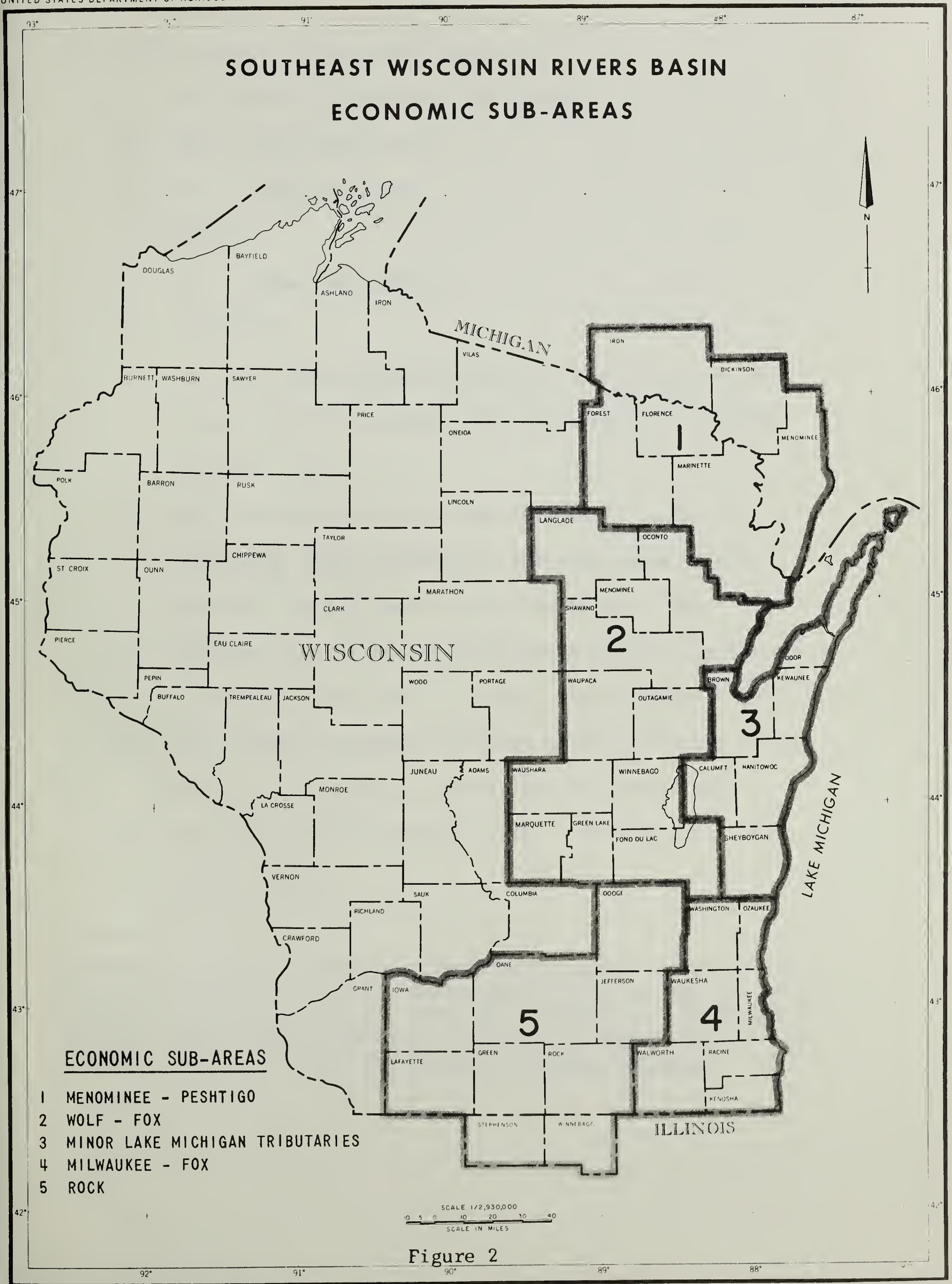

Figure 2

each sector except for the crop sectors. 5/

1. Corn - corn for grain and for silage.
2. Wheat - grain and straw.
3. Oats - grain and straw.
4. Soybeans
5. Hay - legume seed and hay.
6. Vegetables
7. Livestock and livestock products - dairy products, meat animals, poultry products, and miscellaneous livestock products. (1)
8. Food and kindred products manufacturing - vegetable processing, grain processing, prepared feeds, dairy products, and meat and poultry processing. (14)
9. Chemicals and allied products manufacturing - fertilizers, pesticides, herbicides, and drugs and medicines. (27)
10. Farm machinery manufacturing and related services - farm tractors and machinery, repair and services. (44)
11. Petroleum products manufacturing - gasoline, oil, and grease. (31)

5/ U.S. Department of Commerce, National Economics Division, "The Transaction Table of the 1958 Input-Output Study and Revised Direct and Total Requirements Data," XLV, No. 9 (1965), pp. 33-49 and P. 56; and "Input-Output Structure of the U.S. Economy: 1963, "XLIX, No. 11 (1969), pp. 16-47, The Survey of Current Business.

12. Trade and service - major items included in this sector are trading and transportation margins, veterinarian services, finance, insurance, and Dairy Herd Improvement Association fees. (4, 65, 69, 70, and 73; Sector 4 is agricultural, forestry and fishery services, sector 65 is transportation and warehousing, sector 69 is wholesale and retail trade, sector 70 is finance and insurance, and sector 73 is business services).

Sectors one through six represent the major crops produced in the study area. These are the sectors directly affected by resource development projects. In the national studies agriculture is represented by two sectors. One of these is livestock and livestock products and the other is composed of all other agricultural products. Detailed information on seventeen subsectors (four for the livestock sector and thirteen for the other agriculture sector) used to construct the two national sectors for the 1958 model is available (30).

Demonstration for Implementation in the SEWRB Study

As discussed earlier, the Southeast Wisconsin study is directed toward the identification of potentially feasible Public Law 566 projects which can be implemented for flood protection, drainage, irrigation, soil and water conservation, fish and wildlife enhancement, water supply, control and reduction of pollution,

and recreational development. Almost every project proposal has the effect of changing local agricultural production. These changes occur because the resource base (either land, water, or both) available for agricultural production is altered by the project. For some projects, agricultural production will increase and for others it will decrease. In some cases, the agricultural commodity mix may change with the production of some crops increasing and others decreasing.

For an individual project, the likely changes in agricultural production are generally identified with a partial budgeting procedure. When evaluating the effect of a program which consists of several of these projects, a linear programming model is used to identify the likely changes in agricultural production. This report contains the information necessary for estimating the consequences of these changes in production on the agricultural related sectors of the economy.

After the changes in value of agricultural output for a given subregion are determined, the impacts on the related sectors can be estimated using the sectoral multipliers presented in Table 2. Reading from the table, it can be seen that for every dollar change in the value of corn production in Subregion One, total spending of $1.664 is required. Of this total, $1.00 represents the initial change in value of corn production, $0.309 represents respending effects in related industries located in Subregion One, $0.192 represents respending effects in related

Table 2.--IMPACT ON AGRICULTURAL RELATED INDUSTRIES PER DOLLAR OF CHANGE IN VALUE OF AGRICULTURAL PRODUCTION BY SUBREGION

Sector	Subregion One	Rest of the Basin	Rest of the World	Total
Corn	1.30874	.19201	.16306	1.66381
Wheat	1.35422	.19051	.16536	1.71009
Oats	1.30808	.19440	.13389	1.63637
Soybeans	1.33553	.17943	.15390	1.66886
Hay	1.30697	.23023	.12991	1.66711
Vegetables	1.34119	.11266	.12722	1.58107
Livestock	1.84640	.12774	.07575	2.04989

Sector	Subregion Two	Rest of the Basin	Rest of the World	Total
Corn	1.37197	.09508	.15715	1.62420
Wheat	1.39471	.08604	.15690	1.63765
Oats	1.35377	.12060	.12099	1.59536
Soybeans	1.35180	.07797	.13153	1.56130
Hay	1.40085	.15966	.15841	1.71892
Vegetables	1.40419	.04963	.12723	1.58105
Livestock	1.88932	.07528	.07734	2.04194

Sector	Subregion Three	Rest of the Basin	Rest of the World	Total
Corn	1.33250	.13455	.15715	1.62420
Wheat	1.35416	.12659	.15690	1.63765
Oats	1.32134	.15303	.12099	1.59536
Soybeans	1.31721	.11256	.13153	1.56130
Hay	1.36008	.20043	.15841	1.71892
Vegetables	1.37124	.08258	.12723	1.58105
Livestock	1.86118	.10342	.07734	2.04194

industries located outside of Subregion One but within the basin, and $0.163 represents respending effects that accrue to related industries located outside of the basin. Therefore, a project or program that increases corn production in Subregion One by $100,000 will create approximately $66,400 dollars as the total spending in the agricultural and related sectors above the initial $100,000. It is estimated that $30,900 will remain in Subregion One, $19,200 will accrue to the remainder of the basin and $16,300 will accrue to areas outside of the basin (rest of the nation). 6/

If the increase in value of corn production is offset by corresponding decreases in production in the other subregions (the least-cost linear programming model requires the basin's production to conform to national "needs" and therefore places a maximum on crop production in the basin) compensating decreases in the other subregions can be calculated. The distribution effects in agricultural related sectors can be clearly identified by displaying in a table the increases in economic activity in one subregion and the corresponding decreases in the economic activity in the other regions.

Impact information is useful for evaluating many types of public policies. As another example, consider that a marshy area currently producing $50,000 of vegetables per year in Subregion Two were to be preserved in its natural state for environmental or aesthetic reasons and no offsetting production increases occur elsewhere in the subregion. Total spending among agricultural related

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6/ Respending effects accruing to the rest of the nation or any other region are not to be interpreted as net benefits. It is the distribution or area of incidence of the respending effects which is identified by this procedure. Considerable more work would be required to be able to identify changes in net national product.

businesses as a result of this policy is estimated to decline over $29,000 (.581 x $50,000) in addition to the $50,000 decrease in value of vegetable production.

Implications for Further Study

Several areas mentioned in the previous discussion or in the Appendix need additional study. Some of these areas are briefly reviewed in this section. One of the consequences of using a model which concentrates on the agricultural commodity and related sectors is that impact information for forestry sectors is not developed. If financial and manpower resources permit, future river basin studies can utilize a more comprehensive model which is capable of providing additional information. If forestry impact information is required at some point in the analysis of this river basin study, perhaps some indication of the magnitude of the multipliers can be obtained from other input-output studies.

The results of at least one input-output study completed for an area not unlike the northern part of the Southeast Wisconsin Rivers Basin shows that forestry related activities have important impacts on local communities. 7/ This study utilized a survey as the basic data source. The household sector was treated as an endogenous sector and, therefore, the multipliers are larger than those derived in this river basin study. However, the importance of the forestry sectors to local economies like those in the northern portion of this basin is clearly indicated.

7/ Jay M. Hughes, Forestry in Itasca County's Economy, An Input-Output Analysis, Miscellaneous Report 95, Agricultural Experiment Station, University of Minnesota, 1970. This study developed a 39 sector model. Three sectors were used to represent the forestry industry.

A frequently mentioned criticism of input-output analysis is the assumption of constant technical coefficients. It is difficult to determine the seriousness of this assumption for this study. The agricultural data are based on farm enterprise budgets. Frequently, such information is presented according to an assumed level of technology. When using the modified input-output model for predictive purposes, it is possible to develop the agricultural technical coefficients according to the level of technology expected to exist in the future time period. Sensitivity analyses indicate that only minor changes will result in the interdependence coefficients if some of the technical coefficients change as a result of technological progress or for other reasons (23).

Another area where additional study would be helpful is related to the source of data for the agricultural related industries. Coefficients for these industries were developed from national data. One of the disadvantages of using national data for a regional study is that it seriously restricts the investigator's flexibility in defining sectors. The national model emphasizes manufacturing sectors, whereas a regional input-output model is more useful if it emphasizes trade and service sectors. A related problem is that the data are in producer prices while the data from the enterprise budgets are in purchaser prices. Survey data could be collected on the intra-industry transactions of the agricultural related sectors. By using a limited survey, national data would not have to be used and sectors could be defined which would more closely represent the region under investigation.

For additional studies, it would be desirable to disaggregate some of the sectors. The food and kindred products sector of this model is comparable to sector 14 of the national model. This sector represents a broad aggregation of activities. Hartman suggests that unless this sector is disaggregated, spurious interrelatedness of the economy will be reflected in the interdependence coefficients (10). The food and kindred products sector, the trade and services sector, and the livestock sector are three sectors which, if disaggregated, might provide useful detailed information. At the same time these sectors are being disaggregated, a slight aggregation of the crop sectors might be considered.

Another limitation of this study is the method of calculating interregional trade coefficients. The technique used to estimate leakages can only approximate the regional or subregional coefficients. If more accurate estimates are required for the impact analysis, a survey would very likely be required to establish trade coefficients. It would be desirable to establish two import rows and two export columns for each subregion. One import row, in each of the subregions, would show imports from other subregions in the region (basin) and the remaining rows would show imports from the "rest of the world." Similarly, there would be a column showing exports from each subregion to all other subregions, and a second column to show exports outside of the region. This would refine the technique of estimating how changes in one subregion affect the level of activity in the other subregions.

It should be remembered that the model is intended for an open-static analysis of the intermediate sectors of the economy. If information on personal income is of primary interest in a study, another model should be used. 8/ Certain income multipliers (those referred to in the literature as Type II) cannot be determined with this model.

In deciding whether or not to use this modified model in another study the researcher should ascertain that input-output analysis is appropriate for the problem situation, that close approximation of the interdependence coefficients in the agricultural commodity columns is sufficient, that funds are limited, and that sales multipliers rather than income or employment impacts are of central importance to the study. If these conditions exist, then it is likely that the modified model will be useful in the study.

8/ See J. Dean Jansma and W. B. Back, Local Secondary Effects of Watershed Projects, ERS 178, May, 1964, for a study emphasizing local secondary income effects.

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APPENDIX A

A MATHEMATICAL PRESENTATION OF BASIC INPUT-OUTPUT THEORY

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A MATHEMATICAL PRESENTATION OF BASIC INPUT-OUTPUT THEORY

The input-output table is merely a descriptive arrangement of the transactions occuring within the economy which is useful in and of itself. Several assumptions are required in order to use the input-output framework as a predictive device. Chenery and Clark have specified three assumptions as basic to input-output analysis. [9/] The first of these is that each commodity is supplied by a single industry or sector of production. As noted earlier, the industry or sector is the basic unit of production in input-output analysis. Ideally, we classify the economy by sectors such that each sector produces only one product or service and no other sector produces that product or service. In application this obviously cannot be done. Real-world firms produce more than one product or service and to reduce the number of firms into a manageable number of sectors they must be combined into related industry groups. The error introduced as a result of aggregation will be small when: (a) the sectors have similar input structures or (b) different industry outputs are needed in fixed proportions. These conditions for reducing the error result because the numerical value of the aggregated coefficients are weighted by the proportional importance of the consolidated industries. [10/]

9/ Chenery and Clark, Interindustry Economics, pp. 33-43.
10/ Robert Dorfman, Paul A. Samuelson, Robert M. Solow, Linear Programming and Economic Analysis (New York: McGraw-Hill, 1958) pp. 240-243.

The second basic assumption is that the inputs purchased by each sector are a function only of the level of output of that sector. This absence of substitution among inputs might be the result of constant relative prices or of the technical nature of the production function. The third assumption states that the total effect of carrying on several types of production is the sum of the separate effects. The result of this assumption is to rule out externalities.

The basic accounting relationship for an industry or a sector can be summarized as:

$$(1)\quad X_i - \sum_{j=1}^{n} x_{ij} = Y_i$$

where there are n sectors and

X_i represents the output of the i th sector,

x_{ij} represents sales by the i th sector to the j th sector, and

Y_i represents final demand for products of the ith sector.

If we assume that inputs purchased are a function of output then,

$$(2)\quad x_{ij} = a_{ij} X_j$$

By substituting, where a_{ij} is a proportionality constant equation (1) can be rewritten as:

$$(3)\quad X_i - \sum_{j=1}^{n} a_{ij} X_j = Y_i$$ 11/

11/ When one of the principal objectives of the desired model is to examine changes between regions, interregional extensions to the basic input-output framework are theoretically appealing. In this framework the economy is described in terms of interrelated regions as well as interdependent industries. Each row of the transaction matrix shows the sales from the corresponding industry to each industry in every region. Each column shows the purchases of the corresponding industry from each industry in every region. Final demand and value added are also disaggregated by sector and region. When there are R regions, the matrix of technical coefficients has dimensions of Rn x Rn. In an interregional framework equation (3) becomes:

$$X_i^K - \sum_{L-1}^{R} \sum_{j=1}^{n} a_{ij}^{KL} X_j^L = Y_i^K \qquad i = 1,\ldots,n \qquad K = 1,\ldots,R$$

This system of equations appears as:

$$\begin{aligned}
&X_1 - a_{11}X_1 - a_{12}X_2 \;\dots\; - a_{1n}X_n = Y_1 \\
(4)\quad &-a_{21}X_1 + X_2 - a_{22}X_2 \;\dots\; - a_{2n}X_n = Y_2 \\
&\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\
&-a_{n1}X_1 - a_{n2}X_2 \;\dots\; X_n - a_{nn}X_n = Y_n
\end{aligned}$$

By factoring and detaching the coefficients (4) can be written as matrices:

$$(5)\quad \begin{bmatrix} 1-a_{11} & -a_{12} & \dots & -a_{1n} \\ -a_{21} & 1-a_{22} & \dots & -a_{2n} \\ \dots & \dots & \dots & \dots \\ -a_{n1} & -a_{n2} & \dots & 1-a_{nn} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ \dots \\ X_n \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ \dots \\ Y_n \end{bmatrix}$$

or in matrix notation as:

$$(6)\quad (I-A)\ X = Y$$

where I is a n x n identity matrix.

This shows that the vector of industrial outputs, X, is a function of the specified and fixed structural interrelationships, a_{ij}'s, and the vector of final demand, Y. Solving for X gives:

$$(7)\quad (I-A)^{-1}\ Y = X$$

The coefficients in the A matrix represent direct production requirements. These coefficients represent only the direct requirements per unit of output by sector and do not include any indirect or respending effects. Any change in demand outside of the endogenous sectors requires that the given sector change its direct purchases of

inputs from other sectors. But to change the requirements from the other sectors causes different purchases from still other sectors. The sum of these repercussions generated in the endogenous sectors from the initial change is referred to as the multiplier effect. These multipliers are calculated by subtracting the matrix of technical coefficients from the identity matrix and then inverting the resulting matrix. The inverse matrix, $(I-A)^{-1}$, is referred to as the matrix of interdependence coefficients.

Sectoral multipliers are computed by summing the elements in a column of the $(I-A)^{-1}$ matrix. A sectoral multiplier specifies the total production required from all industries to produce a dollar's worth of final output in that sector.

In application, the levels of final demand are generally determined outside of the model and, together with the inverse matrix, yield estimates of the gross output of each producing sector required to meet the direct and indirect demand originating with the initial increase in each final demand specified. However, the problem defined for this river basin study is somewhat different from the usual input-output study because the exogenous change is in resource supply rather than in final demand. [12/] Initially, some change occurs in the agricultural land or water resource base. The first effect to be determined is the consequence on agricultural output. Partial budgeting and linear programming techniques are used to predict these changes.

12/ L. M. Hartman, "The Input-Output Model and Regional Water Management," Journal of Farm Economics, Vol. 47, No. 5, December, 1965, pp. 1583-91.

These production changes can then be fed into an interindustry model to determine the impacts on interdependent sectors. Technical coefficient and inverse tables for this study are contained in reference 23 of the bibliography. Sectoral multipliers are presented in the tables contained in the text of this report.